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Proceedings of the 5th International Conference on Optics, Photonics and Lasers (OPAL' 2022)

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Volume Gratings for the recording of a waveguide on photopolymers

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Summary: In this work we present an application of volume transmission gratings for the coupling of light inside and outside a holographic waveguide. The volume gratings were recorded on photopolymer, since thay have demonstrated great advantages over other materials. The gratings were fabricated with a spatial frequency of 1700 lines/mm so as to couple light inside the glass substrate under total reflection condition. The results demonstrate the efficiency of this device to be used in augmented reality applications, for example as see-through glasses.

Keywords: Waveguides, Photopolymers, Diffraction gratings, Holography, Volume holographic elements

1. Introduction

It is a fact that augmented reality or virtual reality has taken on importance in society. Augmented Reality devices usually consist of a headset and a display system to show the user the virtual information that is added to the real one. In the particular case of the application of these concepts to the fabrication of see-through systems, these have been very welcomed by the general public, since they posses the advantage of being hands-free and have high privacy character.

For the fabrication of these devices planar waveguide technology with holographic optical elements has been widely used [1-3]. The system to be developed consists mainly of three parts: two holographic optical elements coupling the input light to the waveguide and also extracting the light from the substrate, and the glass that acts as a substrate for the holographic material acting as a waveguide by the phenomenon of total internal reflection. In this particular work the two holographic elements used are simple volume gratings recorded on photopolymer material.

The use of photopolymers for the recording of the holographic optical elements is due to the fact that these materials posses important characteristics such as low price, self-processing capability and a high versatility that, offer significant advantages over conventional wet-type recording materials [4].

2. Theoretical Device

In order to fabricate an holographic waveguide on photopolymers using volume gratings, two holographic optical elements must be recorded at a certain distance between them. The first hologram couples the light to the waveguide in total reflection condition, while the second hologram couples the beam out of the waveguide. In order to work as couplers the transmission holographic gratings should couple the incident light between air and the glass substrate accomplishing total internal reflection. Figure 1 shows the configuration of the gratings; the diffracted beam must form the critical angle (total internal reflection) with respect to the normal of the glass substrate. $\vec{k}_r$ and $\vec{k}_o$ are the propagation vectors of the reference (incident) and object (diffracted) beam respectively, $\vec{K}$ is the grating vector and θ_g is the critical angle inside the photopolymer.

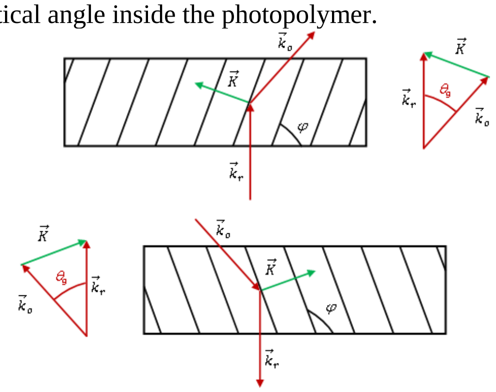

Fig. 1. Volume gratings used for wave coupling.

The grating vector is defined as:

$$\vec{K} = \vec{k}_r - \vec{k}_o, \tag{1}$$

And it is related to the spatial frequency, *f*, and the period of the grating, Λ, by:

$$|\vec{K}| = 2\pi f = \frac{2\pi}{\Lambda}, \tag{2}$$

The angle φ formed by the interference fringes with the substrate can be calculated by using:

$$\varphi = \mathrm{atan}\left(\frac{K_y}{K_x}\right) - \frac{\pi}{2}, \qquad (3)$$

Using equations (1)-(3) it is possible to design the diffraction gratings needed to create the waveguide according to the requirements of the device.

3. Experimental setup

The proposed waveguide is recorded on the photopolymer material using a wavelength of 532 nm, and it is reconstructed by using a He-Ne laser, 632.8 nm, giving a propagation angle inside the layer higher of 41.5°, to obtain total reflection inside the substrate and guide the light.

The experimental device is an asymmetric transmission holographic setup. A Nd:YAG laser tuned at a wavelength of 532 nm was used to record diffraction gratings by means of continuous laser exposure. The laser beam was split into two secondary beams with an intensity ratio of 2.5:1. The diameter of these beams was increased to 1 cm using a spatial filter and collimating lens, while spatial filtering was ensured. The working intensity at 532 nm was 2.5 mW/cm^2 and 1.0 mW/cm^2 for up and down arms. Slanted gratings of 1700 lines/mm were recorded; to do this, the reference beam formed an angle to the normal of −4.8 º, whereas the object beam formed an angle of 68º. We monitored in real time the diffraction grating using red light (λ = 633 nm which the dyes do not absorb) using close to normal incidence (0.3º). After recording, the sample was rotated to record the angular response around the first Bragg condition

4. Results and discussion

Figure 2 shows the transmission efficiency as a function of the angle for a slanted transmission grating recorded on photopolymer material. The spatial frequency of the gratings is of 1700 lines/mm and as can be seen from the figure a high diffraction efficiency of 70% was achieved. On the other hand in Figure 3 a waveguide fabricated on photopolymer material by using two volume transmission diffraction gratings is presents; where two facts must be pointed out, the ability of the waveguide to propagate light by total internal reflection, and the efficiency of the two volume gratings to couple light inside and outside the waveguide.

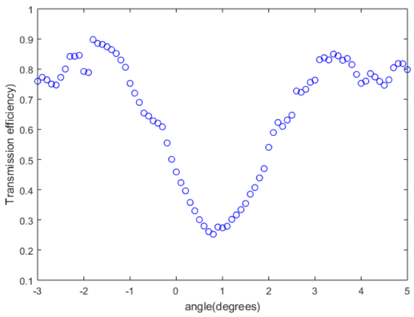

Fig. 2. Transmission efficiency of a volume grating with a spatial frequency of 1700 lines/mm.

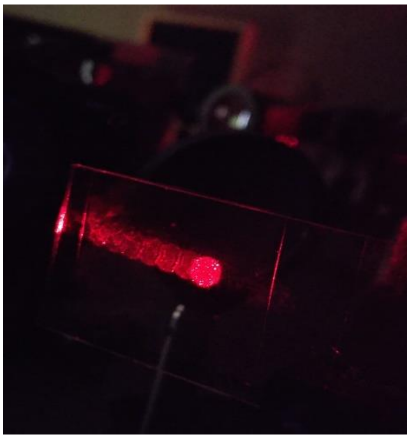

Fig. 3. Waveguide recorded on photopolymer.

5. Conclusions

In this work we have presented an application of volume transmission gratings for the coupling of light inside and outside a holographic waveguide. The volume gratings were recorded on photopolymer, and were fabricated with a spatial frequency of 1700 lines/mm so as to couple light inside the glass substrate under total reflection condition. The volume gratings recorded show a diffraction efficiency of 70% and the waveguide fabricated demonstrates the efficiency of this device to be used in augmented reality applications, for example as see-through glasses.

Acknowledgements

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